

Development of Global Heat and Freshwater Anomaly Analyses

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1. PROJECT SUMMARY

Understanding global climate variability requires knowledge of ocean temperature and salinity fields (or more precisely ocean heat and fresh water content). Accurate estimates of changes in distribution of ocean heat and fresh water content combined with an analysis of how thermohaline (temperature-salinity) anomalies enter, circulate within, and leave the ocean is necessary to monitor and understand interannual to decadal changes in climate. Such fields and analyses help to verify climate models and improve their predictive skill. They help to diagnose the components of sea level change (ocean temperature variations versus ocean mass variations).

This project is developing, updating, and analyzing global analyses of ocean temperature and salinity using quality-controlled compilations of in situ temperature and salinity data from CTD-equipped autonomous profiling floats (Argo), shipboard Conductivity-Temperature-Depth (CTD) instruments, eXpendable Bathy Thermographs (XBTs), moored buoys, and other sources. These data are used to estimate global ocean temperature and salinity fields, hence ocean heat and freshwater content variations, on annual time-scales. Historically, in situ data distributions are relatively sparse, especially before the advent of Argo. However, variations in ocean heat content are closely related to variations in sea-surface height, which has been very well measured since late 1992 by satellite altimeters. By exploiting this close relationship, we are able to quantify sampling errors inherent in estimating a global average of upper ocean heat content from an incomplete data set. We can also exploit the relationship to improve maps of ocean heat content from in situ data by using the altimeter data with local correlation coefficients applied as a first guess at upper ocean heat content in poorly measured regions.

This project, a part of the NOAA Office of Climate Observations Ocean Observing System Team of Experts, by providing analyses of ocean data, helps NOAA to use and assess the effectiveness of the sustained ocean observing system for climate. The work is primarily carried out at NOAA's Pacific Marine Environmental Laboratory by the PMEL and JIMAR investigator, but in very close consultation with the co-investigator at NASA's Jet Propulsion Laboratory.

2. PROJECT ACCOMPLISHMENTS

In FY2008 yearly ocean heat content maps were made by combining in situ temperature profiles with sea surface height anomalies from satellite altimeter data for 1993 through 2007 and reported upon (Johnson et al. 2008). Sea surface salinity maps were also made for 2005 through 2007 and reported upon (Johnson and Lyman, 2008). We wrapped up our study on the effects of sparse historical in situ ocean temperature

sampling patterns on global integrals of upper ocean heat content changes (Lyman and Johnson, 2008). Work also continued on quantifying and documenting two sets of instrument errors, XBT fall rate errors and misreported Argo float pressures (Wijffels et al., 2008; Willis et al., 2008).

We updated maps (e.g. Figure 1) of annual upper (0-750 m) ocean heat content primarily for the ice-free portions of the globe from 1993 through 2007 combining in-situ and satellite altimetry data (following Willis et al. 2004) to better resolve smaller (sub-gyre) scale spatial variability over shorter (year-to-year) time-scales for the 2007 State of the Climate Report (Johnson et al., 2008). Prior to making these maps, we removed Argo float profile data with known potential serious pressure biases from our database, and applied the annual fall rate correction estimates for deep and shallow XBT probe data from Wijffels et al. (2008). Johnson et al. (2008) discuss the results.

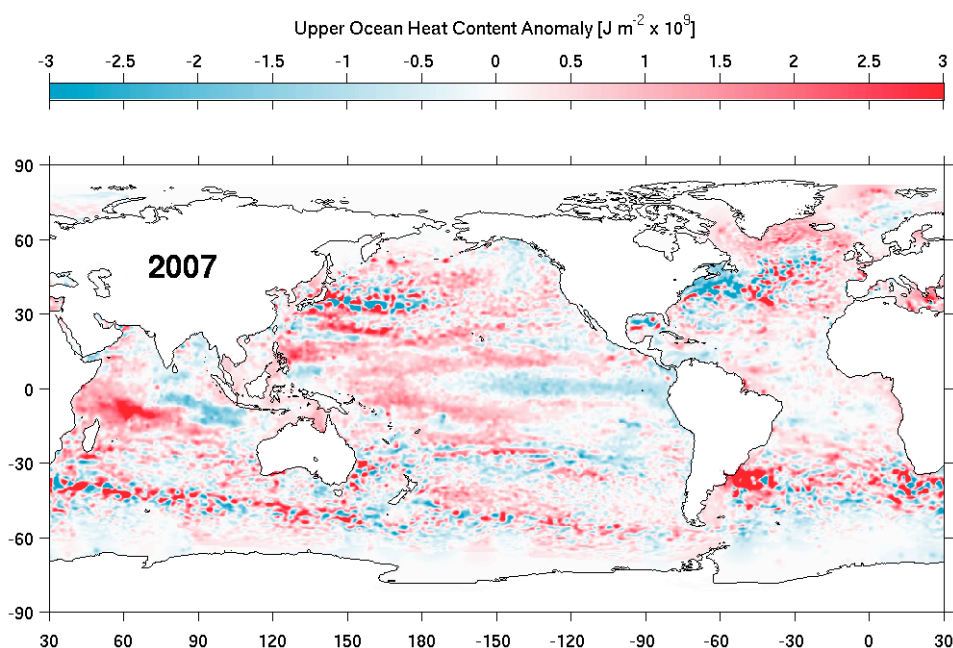


Figure 1. Combined satellite altimeter and in situ ocean temperature data upper (0 – 750 m) ocean heat content anomaly OHCA (J m^{-2}) map for 2007 (top panel) analyzed following Willis et al. (2004), but relative to a 1993 – 2007 baseline. Figure after Johnson et al. (2008).

We continued producing annual average maps of Sea-Surface Salinity (SSS) anomalies with respect to the World Ocean Atlas 2001 Climatology for the 2007 State of the Climate Report (Johnson and Lyman, 2008). These maps (e.g. Figure 2) are only robust for 2005 through 2007, when Argo provided near-global coverage of SSS data. Johnson and Lyman (2008), discuss these results.

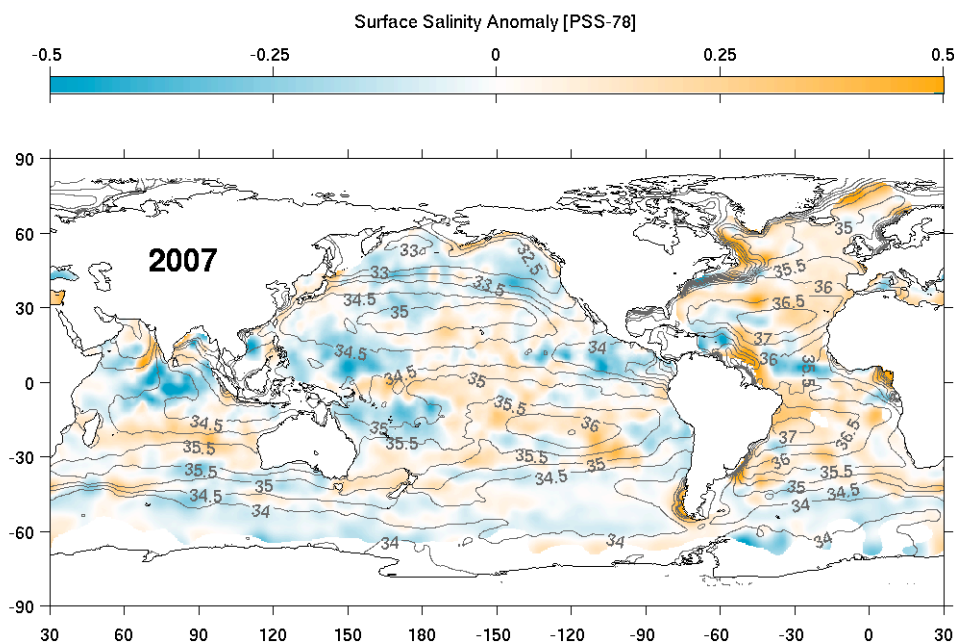


Figure 2. Map of the 2007 annual surface salinity anomaly estimated from Argo data [colors in PSS-78] with respect to a climatological salinity field from WOA 2001 [gray contours at 0.5 PSS-78 intervals]. White areas are either neutral with respect to salinity anomaly or are too data-poor to map. While salinity is often reported in practical salinity units, or PSU, it is actually a dimensionless quantity reported on the 1978 Practical Salinity Scale, or PSS-78. Figure after Johnson and Lyman (2008).

Last year's progress report discussed the effects of sparse in situ temperature profile distributions in pre-Argo years in detail, so that work is not summarized again here. Similarly, the XBT fall rate errors and misreported Argo float pressures were discussed previously and that discussion is not repeated here.

Manuscripts related to this project that were published or submitted for publication in FY2008 are listed below. The project web page is <http://oceans.pmel.noaa.gov/>.

3. PUBLICATIONS AND REPORTS

Johnson, G. C., and J. M. Lyman, 2008: Global Oceans: Sea Surface Salinity. *In State of the Climate in 2007*, D. H. Levinson and J. H. Lawrimore, Eds., *Bulletin of the American Meteorological Society*, **89**, 7, S45–S47, doi:10.1175/BAMS-89-7-StateoftheClimate.

Johnson, G. C., J. M. Lyman, and J. K. Willis, 2008: Global Oceans: Ocean Heat Content. *In State of the Climate in 2007*, D. H. Levinson and J. H. Lawrimore, Eds., *Bulletin of the American Meteorological Society*, **89**, 7, S39–S41, doi: 10.1175/BAMS-89-7-StateoftheClimate.

Lyman, J. M., and G. C. Johnson. 2008a: Equatorial Kelvin Wave influences may reach the Bering Sea during 2002 to 2005. *Geophysical Research Letters*, **35**, L14607, doi:10.1029/2008GL034761.

Lyman, J. M., and G. C. Johnson. 2008b: Estimating global upper ocean heat content despite irregular sampling. *Journal of Climate*, doi:10.1175/2008JCLI2259.1.

Wijffels, S. E., J. Willis, C. M. Domingues, P. Barker, N. J. White, A. Gronell, K. Ridgway, and J. A. Church, 2008: Changing eXpendable Bathythermograph Fall-rates and their Impact on Estimates of Thermosteric Sea Level Rise, *Journal of Climate*, in press, doi:10.1175/2008JCLI2290.1

Willis, J. K., D. P. Chambers, and R. S. Nerem, 2008a: Closing the Globally Averaged Sea Level Budget on Seasonal to Interannual Time Scales. *Journal of Geophysical Research - Oceans*, **113**, C06015, doi:10.1029/2007JC004517.

Willis, J. K., J. M. Lyman, J. M., G. C. Johnson, and J. Gilson, 2008b: In situ data biases and recent ocean heat content variability. *Journal of Atmospheric and Oceanic Technology*, doi:10.1175/2008JTECHO608.1.